CHARACTERIZATION OF SHORT PINEAPPLE LEAF FIBER REINFORCED TAPIOCA BIOPOLYMER COMPOSITES

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Doctor of Philosophy

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

We hereby declare that We have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Pembangunan bahan mesra alam seperti komposit serat semulajadi semakin mendapat perhatian dalam beberapa tahun kebelakangan ini disebabkan oleh peningkatan kesedaran terhadap alam sekitar berhubung dengan pelbagai kesan buruk yang telah dihasilkan oleh polimer berasaskan petroleum. Di antara kesemua serat semulajadi, serat daun nanas (PALF) mempunyai potensi besar sebagai agen pengukuhan komposit kerana kosnya yang rendah, ketersediaan yang tinggi, kandungan selulosa yang tinggi dan sifat mekanik yang relatifnya lebih tinggi berbanding dengan serat semulajadi yang lain. Dalam kebanyakan penyelidikan terdahulu, PALF digunakan sebagai penguat dalam polimer berasaskan petroleum yang tidak terbiodegradasi bagi menghasilkan komposit serat semulajadi. Walau bagaimanapun, inovasi polimer berasaskan kanji yang dipanggil biopolimer ubi kayu (TBP) menyediakan alternatif sebagai matriks biodegradasi untuk pembangunan komposit mesra alam. Oleh itu, gabungan PALF dan TBP dalam pembangunan komposit bio kelihatan seimbang antara perspektif ekologi dan ekonomi. Sebagai gabungan baru, penyelidikan ini dijalankan untuk menentukan parameter gabungan optimum komposit PALF-TBP dalam menghasilkan sifat mekanik yang kompetitif. Terdapat empat pertimbangan penting dalam pembuatan komposit dalam menghasilkan sifat mekanik yang tinggi seperti suhu pemprosesan yang digunakan dalam proses pembuatan, panjang serat, peratusan kandungan serat dan rawatan yang terlibat. Kerja eksperimen bermula dengan proses pencirian bahan TBP dan PALF. Selepas itu, penyediaan sampel yang dijalankan terdiri daripada proses menghancurkan serat dan pengasingan, proses pencampuran dalaman, pengacuan mampatan dan proses pemesinan. Sampel TBP dengan suhu pemprosesan yang berbeza (160°C, 165°C, 170°C, 175°C, 180°C dan 185°C) disediakan untuk menentukan suhu pemprosesan optimum TBP. Selain itu, sampel komposit dengan panjang serat yang berbeza (≤ 0.50 mm, 0.51-1.00 mm dan 1.01-2.00 mm) dan kandungan serat yang berbeza (10%, 20%, 30% dan 40%) disediakan untuk menilai kesan variasi panjang serat dan peratusan serat pada sifat mekanikal komposit PALF-TBP. Selain itu, tiga rawatan yang berbeza telah dipilih iaitu compatibilizer maleic anhydride polypropylene (MAPP), compatibilizer maleic anhidride polietilena (MAPE) dan rawatan alkali untuk penyiasatan kesan rawatan terhadap sifat tegangan komposit PALF-TBP. Analisis untuk menentukan keseluruhan objektif penyelidikan terdiri daripada analisis sifat terma, dan analisis sifat mekanik. Di samping itu, pemeriksaan mikroskop elektron (SEM) telah dijalankan sebagai pengesahan keputusan. Hasil kajian mendapati bahawa suhu pemprosesan optimum untuk TBP adalah 165°C hingga 170°C dan kombinasi terbaik untuk pembangunan komposit TBP yang diperkuatkan oleh PALF pendek adalah yang dihasilkan oleh pengacuan mampatan yang terdiri daripada 30% kandungan serat dan 7% kandungan agen gandingan MAPP. Walau bagaimanapun, pengaruh pelbagai panjang serat sehingga 2.00 mm tidak memberikan pengaruh yang signifikan ke atas menghasilkan sifat tegangan maksimum. Penemuan ini menunjukkan bahawa gabungan PALF dan TBP yang pendek mempunyai potensi besar sebagai komposit mesra alam untuk menjadi alternatif kepada polimer konvensional dalam aplikasi kejuruteraan terutamanya dalam sektor automotif. Peningkatan pembangunan komposit PALF-TBP pada masa akan datang seperti penggunaan PALF dengan kekuatan tegangan yang lebih tinggi yang diharapkan mampu meningkatkan dan memperbaiki hasil yang ada sekarang.

ABSTRACT

The development of environmental friendly material, such as natural fiber composites, has been getting more attention in recent years due to increase in environmental awareness of various adverse petroleum-based polymer effects. Among all natural fibers, pineapple leaf fiber (PALF) has great potential as a reinforcement agent because it is low cost, highly available with high cellulose content, and has relatively higher mechanical properties as compared to other natural fibers. Most previous research works had used PALF as reinforcement in non-biodegradable petroleum-based polymers to produce natural fiber composites. However, the starch-based polymer innovation, called tapioca biopolymer (TBP), provides an alternative for biodegradable matrix for the development of environmental friendly composites. Therefore, the combination of PALF and TBP in bio-composites development appears to be a perfect balance between the ecology and economic perspectives. As a new combination, this research was conducted to determine the optimum PALF-TBP composites combination parameters to produce competitive mechanical properties. To produce high mechanical properties, there are four essential considerations in the preparation of composites, such as the manufacturing process temperature, fiber length, fiber composition and treatment involved. The experimental work began with material characterization of TBP and PALF. Then, sample preparation was conducted, which consisted of fiber crushing and sieving, internal mixing, hot press and machining. TBP samples at different processing temperatures (160°C, 165°C, 170°C, 175°C, 180°C and 185°C) were prepared to determine the optimum processing temperature. Also, composite samples with different fiber lengths (0.10-0.50 mm, 0.51-1.00 mm and 1.01-2.00 mm) and different fiber loadings (10%, 20%, 30% and 40%) were prepared to evaluate the effect of varying fiber lengths and fiber loadings on mechanical properties of PALF-TBP composites. On the other hand, three different treatments were selected, which were maleic anhydride polypropylene (MAPP) compatibilizer, maleic anhydride polyethylene (MAPE) compatibilizer and alkali treatment for investigating the treatment effect on tensile properties of PALF-TBP composites. The analyses to determine the entire research objective consisted of thermal properties analysis and mechanical properties analysis. In addition, the scanning electron microscopy (SEM) analysis was carried out for result validation. Test results established that the optimum processing temperatures for TBP are 165°C to 170°C with the best combination for the development of short PALF reinforced TBP composite was produced by a hot press process, comprising 30% fiber loading and 7% MAPP coupling agent. However, the influence of various fiber lengths of up to 2.00 mm provided no significant influence on the production of maximum tensile properties. The finding demonstrated that the combination of short PALF and TBP had great potential as environmental friendly composites to be an alternative for the conventional polymers in engineering applications, especially in the automotive sector. Improvement of future PALF-TBP composites development, such as the utilization of PALF with higher tensile strength, is expected to be capable of enhancing and improving the present result.

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LIST OF SYMBOLS

α	Alpha
β	Beta
cm	Centimeter
°C	Degree Celsius
E	Margin of error for statistical application
E	Chord modulus
ε	Strain value
GPa	Giga Pascal
g	Gram
h	Hour
J	Joule
kJ	Kilo Joule
kN	Kilo Newton
m	Meter
min	Minutes
ml	Mililiter
MPa	Mega Pascal
M_a	Weight of air-dried sample
M_c	Weight of crucible
M_{cl}	Weight of crucible containing lignin content
M_o	Weight of oven-dried sample
N	Newton
n	Sample size
n_1	Sample size for group 1
n_2	Sample size for group 2
°	Degree
σ	Stress value
σ_f	Tensile strength of natural fiber
σ_m	Tensile strength of matrix
S	Standard deviation
S_1	Standard deviation for group 1
S_2	Standard deviation for group 2
υ	Degree of freedom for statistical application
υ_f	Composition of fiber
υ_m	Composition of matrix

w/v	Weigt per volume
$\bar{x}$	Mean
$\bar{x}_1$	Mean for population group 1
$\bar{x}_2$	Mean for population group 2
γ	Gamma
%	Percent

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
ATR	Attenuated Total Reflectance
CMC	Ceramic Matrix Composites
CNC	Computer Numerical Control
DSC	Differential Scanning Calorimetry
FL	Fiber Length
FTIR	Fourier Transform Infrared Spectroscopy
HDPE	High-Density Polyethylene
ICBP	Indochine Bio Plastiques
IUPAC	International Union of Pure and Applied Chemistry
LDPE	Low-Density Polyethylene
MAPE	Maleic Anhydride Polyethylene
MAPP	Maleic Anhydride Polypropylene
MMC	Metal Matrix Composite
NaOH	Sodium Hydroxide
PALF	Pineapple Leaf Fiber
PBS	Poly (Butylene Succinate)
PC	Polycarbonate
PE	Polyethylene
PET	Polyethylene Terephthalate
PLA	Polylactic Acid
PMC	Polymer Matrix Composites
PP	Polypropylene
PU	Polyurethane
PVC	Polyvinylchloride
SEM	Scanning Electron Microscopy
TAPPI	Technical Association of the Pulp and Paper Industry
TBP	Tapioca Biopolymer
TGA	Thermogravimetric Analysis
UNFCC	United Nations Framework Convention on Climate Change

REFERENCES

Addivant. (2018). POLYBOND® 3200 polymer modifier. Retrieved from https://www.addivant.com/ accessed on 18/07/2018

Ahmad, F., Choi, H. S., & Park, M. K. (2015). A review: natural fiber composites selection in view of mechanical, light weight, and economic properties. *Macromolecular materials and Engineering, 300*(1), 10-24.

Ahmad, I., Mosadeghzad, Z., Daik, R., & Ramli, A. (2008). The effect of alkali treatment and filler size on the properties of sawdust/UPR composites based on recycled PET wastes. *Journal of Applied Polymer Science, 109*(6), 3651-3658.

Aji, I. S., Zainudin, E. S., Khalina, A., Sapuan, S., & Khairul, M. (2011). Studying the effect of fiber size and fiber loading on the mechanical properties of hybridized kenaf/PALF-reinforced HDPE composite. *Journal of Reinforced Plastics and Composites, 30*(6), 546-553.

Al-Oqla, F. M., Sapuan, S., Ishak, M., & Nuraini, A. (2016). A decision-making model for selecting the most appropriate natural fiber–Polypropylene-based composites for automotive applications. *Journal of Composite Materials, 50*(4), 543-556.

Alam, M. M., Ahmed, T., Haque, M. M., Gafur, M., & Kabir, A. H. (2008). Mechanical properties of natural fiber containing polymer composites. *Polymer-Plastics Technology and Engineering, 48*(1), 110-113.

Ali, B. A., Sapuan, S., Zainudin, E., & Othman, M. (2015). Implementation of the expert decision system for environmental assessment in composite materials selection for automotive components. *Journal of Cleaner Production, 107*, 557-567.

Allen, T. T. (2006). *Introduction to engineering statistics and six sigma: statistical quality control and design of experiments and systems*: Springer Science & Business Media.

Amuthakkannan, P., Manikandan, V., Jappes, J. W., & Uthayakumar, M. (2013). Effect of fibre length and fibre content on mechanical properties of short basalt fibre reinforced polymer matrix composites. *Materials Physics and Mechanics, 16*, 107-117.

Arib, R., Sapuan, S., Ahmad, M., Paridah, M., & Zaman, H. K. (2006). Mechanical properties of pineapple leaf fibre reinforced polypropylene composites. *Materials & Design, 27*(5), 391-396.

Arkema. (2018). Orevac® resins. Retrieved from https://www.arkema.com accessed on 18/07/2018

Asim, M., Jawaid, M., Abdan, K., & Ishak, M. R. (2016). Effect of Alkali and Silane Treatments on Mechanical and Fibre-matrix Bond Strength of Kenaf and Pineapple Leaf Fibres. *Journal of Bionic Engineering, 13*(3), 426-435.

ASTM. (1994). ASTM D5488-94de1 Standard Terminology of Environmental Labeling of Packaging Materials and Packages (Withdrawn 2002). West Conshohocken, PA: ASTM International.

ASTM. (2002). ASTM D790-02 Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. West Conshohocken, PA: ASTM International.

ASTM. (2003a). ASTM C1557-03 Standard Test Method for Tensile Strength and Young's Modulus of Fibers. West Conshohocken, PA: ASTM International.

ASTM. (2003b). ASTM D 638-03 Standard Test Method for Tensile Properties of Plastics. West Conshohocken, PA: ASTM International.

ASTM. (2003c). ASTM D 3418-03 Standard Test Method for Transition Temperatures of Polymers By Differential Scanning Calorimet. West Conshohocken, PA: ASTM International.

ASTM. (2003d). ASTM D 6370-99 (Reapproved 2003) Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA). West Conshohocken, PA: ASTM International.

ASTM. (2010). ASTM D256-10 Standard Test Method for Determining the Izod Pendulum Impact Resistance of Plastics. West Conshohocken, PA: American Society for Testing and Material.

Avérous, L. (2004). Biodegradable multiphase systems based on plasticized starch: a review. *Journal of Macromolecular Science, Part C: Polymer Reviews, 44*(3), 231-274.

Azwa, Z., Yousif, B., Manalo, A., & Karunasena, W. (2013). A review on the degradability of polymeric composites based on natural fibres. *Materials & Design, 47*, 424-442.

Bachtiar, D., Sapuan, S., & Hamdan, M. (2008). The effect of alkaline treatment on tensile properties of sugar palm fibre reinforced epoxy composites. *Materials & Design, 29*(7), 1285-1290.

Balan, A. K., Parambil, S. M., Vakyath, S., Velayudhan, J. T., Naduparambath, S., & Etathil, P. (2017). Coconut shell powder reinforced thermoplastic polyurethane/natural rubber blend-composites: effect of silane coupling agents on the mechanical and thermal properties of the composites. *Journal of materials science, 52*(11), 6712-6725.

Beg, M., & Pickering, K. (2008). Mechanical performance of Kraft fibre reinforced polypropylene composites: Influence of fibre length, fibre beating and hygrothermal ageing. *Composites Part A: Applied Science and Manufacturing, 39*(11), 1748-1755.

Bijarimi, M., Piah, M., Sahrim, A., & Rozaidi, R. (2012). Mechanical, thermal and morphological properties of PLA/PP melt blends.

Binoj, J., Raj, R. E., Sreenivasan, V., & Thusnavis, G. R. (2016). Morphological, physical, mechanical, chemical and thermal characterization of sustainable Indian areca fruit husk fibers (Areca catechu L.) as potential alternate for hazardous synthetic fibers. *Journal of Bionic Engineering, 13*(1), 156-165.

Bioplastics, E. (2017). Bioplastic materials. Retrieved from https://www.european-bioplastics.org accessed on 10/04/2018

Bledzki, A. K., & Faruk, O. (2004). Wood fiber reinforced polypropylene composites: Compression and injection molding process. *Polymer-Plastics Technology and Engineering, 43*(3), 871-888.

Broutman, L., & McGarry, F. (1965). Fracture surface work measurements on glassy polymers by a cleavage technique. I. Effects of temperature. *Journal of Applied Polymer Science, 9*(2), 589-608.

Callister Jr, W. D., & Rethwisch, D. G. (2012). *Fundamentals of materials science and engineering: an integrated approach*: John Wiley & Sons.

Cao, Y., Shibata, S., & Fukumoto, I. (2006). Mechanical properties of biodegradable composites reinforced with bagasse fibre before and after alkali treatments. *Composites Part A: Applied Science and Manufacturing, 37*(3), 423-429.

Chaudhuri, S., Chakraborty, R., & Bhattacharya, P. (2013). Optimization of biodegradation of natural fiber (Chorchorus capsularis): HDPE composite using response surface methodology. *Iranian Polymer Journal, 22*(11), 865-875.

Cherian, B. M., Leão, A. L., de Souza, S. F., Costa, L. M. M., de Olyveira, G. M., Kottaisamy, M., . . . Thomas, S. (2011). Cellulose nanocomposites with nanofibres isolated from pineapple leaf fibers for medical applications. *Carbohydrate polymers, 86*(4), 1790-1798.

Chew Chong Bew, L. M. S., Ong Beng Sim. (1998). *Statistik*. Kuala Lumpur, Malaysia: Penerbit Fajar Bakti Sdn Bhd.

Chiao, C., Chiao, T., & Lubin, G. (1982). Handbook of Composites. *by G. Lubin, Van Nostrand Reinhold, New York*.

Devi, L. U., Bhagawan, S., & Thomas, S. (1997). Mechanical properties of pineapple leaf fiber-reinforced polyester composites. *Journal of Applied Polymer Science, 64*(9), 1739-1748.

Dhakal, H., Zhang, Z., & Richardson, M. (2007). Effect of water absorption on the mechanical properties of hemp fibre reinforced unsaturated polyester composites. *Composites Science and Technology, 67*(7), 1674-1683.

Du, Y., Wu, T., Yan, N., Kortschot, M. T., & Farnood, R. (2014). Fabrication and characterization of fully biodegradable natural fiber-reinforced poly (lactic acid) composites. *Composites Part B: Engineering, 56*, 717-723.

Duval, A., Bourmaud, A., Augier, L., & Baley, C. (2011). Influence of the sampling area of the stem on the mechanical properties of hemp fibers. *Materials Letters, 65*(4), 797-800.

Edhirej, A., Sapuan, S., Jawaid, M., & Zahari, N. I. (2017a). Cassava/sugar palm fiber reinforced cassava starch hybrid composites: Physical, thermal and structural properties. *International Journal of Biological Macromolecules, 101*, 75-83.

Edhirej, A., Sapuan, S., Jawaid, M., & Zahari, N. I. (2017b). Preparation and characterization of cassava bagasse reinforced thermoplastic cassava starch. *Fibers and Polymers, 18*(1), 162-171.

El-Sabbagh, A. (2014). Effect of coupling agent on natural fibre in natural fibre/polypropylene composites on mechanical and thermal behaviour. *Composites Part B: Engineering, 57*, 126-135.

El-Shekeil, Y., Sapuan, S., Abdan, K., & Zainudin, E. (2012). Influence of fiber content on the mechanical and thermal properties of Kenaf fiber reinforced thermoplastic polyurethane composites. *Materials & Design, 40*, 299-303.

Fairuz, A., Sapuan, S., Zainudin, E., & Jaafar, C. (2015). The effect of gelation and curing temperatures on mechanical properties of pultruded kenaf fibre reinforced vinyl ester composites. *Fibers and Polymers, 16*(12), 2645-2651.

Fuqua, M., & Ulven, C. (2008). Characterization of polypropylene/corn fiber composites with maleic anhydride grafted polypropylene. *Journal of Biobased Materials and Bioenergy, 2*(3), 258-263.

Garlotta, D. (2001). A Literature Review of Poly(Lactic Acis). *Journal of Polymers and the Environmet, 9*(2), 22.

Gassan, J., & Bledzki, A. K. (1997). The influence of fiber-surface treatment on the mechanical properties of jute-polypropylene composites. *Composites Part A: Applied Science and Manufacturing, 28*(12), 1001-1005.

Gay, D., Hoa, S., & Tsai, S. (2007). Ply Properties. *Composite Materials: Design and Applications*.

George, J., Bhagawan, S., & Thomas, S. (1996a). Thermogravimetric and dynamic mechanical thermal analysis of pineapple fibre reinforced polyethylene composites. *Journal of thermal analysis, 47*(4), 1121-1140.

George, J., Janardhan, R., Anand, J., Bhagawan, S., & Thomas, S. (1996b). Melt rheological behaviour of short pineapple fibre reinforced low density polyethylene composites. *Polymer, 37*(24), 5421-5431.

Gilbert, M., & Hybart, F. (1972). Effect of chemical structure on crystallization rates and melting of polymers: Part 1. Aromatic polyesters. *Polymer, 13*(7), 327-332.

Gong, F., Feng, M., Zhao, C., Zhang, S., & Yang, M. (2004). Thermal properties of poly (vinyl chloride)/montmorillonite nanocomposites. *Polymer Degradation and stability, 84*(2), 289-294.

Gruber, P., & O'Brien, M. (2005). Polylactides "Natureworks® PLA". *Biopolymers Online*.

Hamdan, M., Siregar, J., Bachtiar, D., Rejab, M., Samykano, M., Agung, E., . . . Jaafar, J. (2017). *Effect of alkaline treatment on mechanical properties of woven ramie reinforced thermoset composite.* Paper presented at the IOP Conference Series: Materials Science and Engineering.

Haque, M. M., Hasan, M., Islam, M. S., & Ali, M. E. (2009). Physico-mechanical properties of chemically treated palm and coir fiber reinforced polypropylene composites. *Bioresource Technology, 100*(20), 4903-4906.

Hargitai, H., Rácz, I., & Anandjiwala, R. D. (2008). Development of hemp fiber reinforced polypropylene composites. *Journal of Thermoplastic Composite Materials, 21*(2), 165-174.

Hashemi, W. F. S. a. J. (2011). *Foundation of Materials Science and Engineering* (Fifth SI Edition ed.). Singapore: McGraw-Hill Companies Inc.

Hidayat, P. (2008). Teknologi pemanfaatan serat daun nanas sebagai alternatif bahan baku tekstil. *Jurnal Teknologi Industri, 13*(2), 31-35.

Holbery, J., & Houston, D. (2006). Natural-fiber-reinforced polymer composites in automotive applications. *Jom, 58*(11), 80-86.

Hu, R., & Lim, J.-K. (2007). Fabrication and mechanical properties of completely biodegradable hemp fiber reinforced polylactic acid composites. *Journal of Composite Materials, 41*(13), 1655-1669.

Huda, M. S., Drzal, L. T., Mohanty, A. K., & Misra, M. (2008). Effect of chemical modifications of the pineapple leaf fiber surfaces on the interfacial and mechanical properties of laminated biocomposites. *Composite Interfaces, 15*(2-3), 169-191.

Ibrahim, N. A., Hadithon, K. A., & Abdan, K. (2010). Effect of fiber treatment on mechanical properties of kenaf fiber-ecoflex composites. *Journal of Reinforced Plastics and Composites, 29*(14), 2192-2198.

ICBP. (2017). Technical Data Sheet: ICBP Bio Resin. Retrieved from www.icbp.com.my accessed on 14/12/2017

Jacob, M., Thomas, S., & Varughese, K. T. (2004). Mechanical properties of sisal/oil palm hybrid fiber reinforced natural rubber composites. *Composites Science and Technology, 64*(7), 955-965.

Jamiluddin, J., Siregar, J. P., Sulaiman, A., Jalal, K. A. A., & Tezara, C. (2016). Study on Properties of Tapioca Resin Polymer. *International Journal of Automotive and Mechanical Engineering (IJAME), 13*(1), 3178-3189. doi:http://dx.doi.org/10.15282/ijame.13.1.2016.5.0265

Jawaid, M., & Khalil, H. A. (2011). Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review. *Carbohydrate polymers, 86*(1), 1-18.

John, M. J., & Anandjiwala, R. D. (2008). Recent developments in chemical modification and characterization of natural fiber-reinforced composites. *Polymer composites, 29*(2), 187-207.

John, M. J., & Thomas, S. (2008). Biofibres and biocomposites. *Carbohydrate polymers, 71*(3), 343-364.

Joseph, P., Joseph, K., & Thomas, S. (1999). Effect of processing variables on the mechanical properties of sisal-fiber-reinforced polypropylene composites. *Composites Science and Technology, 59*(11), 1625-1640.

Jumaidin, R., Sapuan, S., Jawaid, M., Ishak, M., & Sahari, J. (2016). Characteristics of thermoplastic sugar palm Starch/Agar blend: Thermal, tensile, and physical properties. *International Journal of Biological Macromolecules, 89*, 575-581.

Jumaidin, R., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2017a). Effect of seaweed on mechanical, thermal, and biodegradation properties of thermoplastic sugar palm starch/agar composites. *International Journal of Biological Macromolecules, 99*, 265-273.

Jumaidin, R., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2017b). Thermal, mechanical, and physical properties of seaweed/sugar palm fibre reinforced thermoplastic sugar palm Starch/Agar hybrid composites. *International Journal of Biological Macromolecules, 97*, 606-615.

Kalapakdee, A., & Amornsakchai, T. (2014). Mechanical properties of preferentially aligned short pineapple leaf fiber reinforced thermoplastic elastomer: Effects of fiber content and matrix orientation. *Polymer testing, 37*, 36-44.

Kalpakjian, S., & Schmid, S. R. (2014). *Manufacturing engineering and technology*: Pearson Upper Saddle River, NJ, USA.

Kang, O. L., Ramli, N., Said, M., Ahmad, M., Yasir, S. M., & Ariff, A. (2011). Kappaphycus alvarezii waste biomass: A potential biosorbent for chromium ions removal. *Journal of Environmental Sciences, 23*(6), 918-922.

Karmarkar, A., Chauhan, S., Modak, J. M., & Chanda, M. (2007). Mechanical properties of wood–fiber reinforced polypropylene composites: Effect of a novel compatibilizer with isocyanate functional group. *Composites Part A: Applied Science and Manufacturing, 38*(2), 227-233.

Kengkhetkit, N., & Amornsakchai, T. (2012). Utilisation of pineapple leaf waste for plastic reinforcement: 1. A novel extraction method for short pineapple leaf fiber. *Industrial Crops and Products, 40*, 55-61. doi:10.1016/j.indcrop.2012.02.037

Khalid, M., Ali, S., Abdullah, L., Ratnam, C., & Choong, S. T. (2006). Effect of MAPP as coupling agent on the mechanical properties of palm fiber empty fruit bunch and cellulose polypropylene biocomposites. *International Journal of Engineering and Technology, 3*(1), 79-84.

Khalil, H. S. A., Alwani, M. S., & Omar, A. K. M. (2007). Chemical composition, anatomy, lignin distribution, and cell wall structure of Malaysian plant waste fibers. *BioResources, 1*(2), 220-232.

Khondker, O. A., Ishiaku, U. S., Nakai, A., & Hamada, H. (2005). Fabrication mechanical properties of unidirectional jute/PP composites using jute yarns by film stacking method. *Journal of Polymers and the Environment, 13*(2), 115-126.

Kim, H.-S., Kim, S., Kim, H.-J., & Yang, H.-S. (2006). Thermal properties of bio-flour-filled polyolefin composites with different compatibilizing agent type and content. *Thermochimica Acta, 451*(1), 181-188.

Kim, J.-H., Shim, B. S., Kim, H. S., Lee, Y.-J., Min, S.-K., Jang, D., . . . Kim, J. (2015). Review of nanocellulose for sustainable future materials. *International Journal of Precision Engineering and Manufacturing-Green Technology, 2*(2), 197-213.

Ku, H., Wang, H., Pattarachaiyakoop, N., & Trada, M. (2011). A review on the tensile properties of natural fiber reinforced polymer composites. *Composites Part B: Engineering, 42*(4), 856-873.

Lee, B.-H., Kim, H.-J., & Yu, W.-R. (2009). Fabrication of long and discontinuous natural fiber reinforced polypropylene biocomposites and their mechanical properties. *Fibers and Polymers, 10*(1), 83-90.

Lee, M. S., Seo, H. Y., & Kang, C. G. (2016). Comparative study on mechanical properties of CR340/CFRP composites through three point bending test by using theoretical and experimental methods. *International Journal of Precision Engineering and Manufacturing-Green Technology, 3*(4), 359-365.

Lelievre, J. (1974). Starch gelatinization. *Journal of Applied Polymer Science, 18*(1), 293-296.

Levchik, S. V., Weil, E. D., & Lewin, M. (1999). Thermal decomposition of aliphatic nylons. *Polymer International, 48*(7), 532-557.

Li, X., Tabil, L., Panigrahi, S., & Crerar, W. (2006). *The influence of fiber content on properties of injection molded flax fiber-HDPE biocomposites.* Paper presented at the 2006 ASAE Annual Meeting.

Lim, M. H., Wu, H., & Reid, D. S. (2000). The effect of starch gelatinization and solute concentrations on Tg′ of starch model system. *Journal of the Science of Food and Agriculture, 80*(12), 1757-1762.

Liu, H., Xie, F., Yu, L., Chen, L., & Li, L. (2009a). Thermal processing of starch-based polymers. *Progress in polymer science, 34*(12), 1348-1368.

Liu, L., Yu, J., Cheng, L., & Qu, W. (2009b). Mechanical properties of poly (butylene succinate)(PBS) biocomposites reinforced with surface modified jute fibre. *Composites Part A: Applied Science and Manufacturing, 40*(5), 669-674.

Liu, W., Drzal, L. T., Mohanty, A. K., & Misra, M. (2007). Influence of processing methods and fiber length on physical properties of kenaf fiber reinforced soy based biocomposites. *Composites Part B: Engineering, 38*(3), 352-359.

Liu, W., Misra, M., Askeland, P., Drzal, L. T., & Mohanty, A. K. (2005). 'Green'composites from soy based plastic and pineapple leaf fiber: fabrication and properties evaluation. *Polymer, 46*(8), 2710-2721.

Loh, Y., Sujan, D., Rahman, M., & Das, C. (2013). Sugarcane bagasse—The future composite material: A literature review. *Resources, Conservation and Recycling, 75*, 14-22.

Lomelí-Ramírez, M. G., Barrios-Guzmán, A. J., García-Enriquez, S., de Jesús Rivera-Prado, J., & Manríquez-González, R. (2014a). Chemical and mechanical evaluation of bio-composites based on thermoplastic starch and wood particles prepared by thermal compression. *BioResources, 9*(2), 2960-2974.

Lomelí-Ramírez, M. G., Kestur, S. G., Manríquez-González, R., Iwakiri, S., de Muniz, G. B., & Flores-Sahagun, T. S. (2014b). Bio-composites of cassava starch-green coconut fiber: Part II—Structure and properties. *Carbohydrate polymers, 102*, 576-583.

Lopattananon, N., Panawarangkul, K., Sahakaro, K., & Ellis, B. (2006). Performance of pineapple leaf fiber–natural rubber composites: the effect of fiber surface treatments. *Journal of Applied Polymer Science, 102*(2), 1974-1984.

Lu, D., Xiao, C., & Xu, S. (2009). Starch-based completely biodegradable polymer materials. *Express polymer letters, 3*(6), 366-375.

Luyt, A., Molefi, J., & Krump, H. (2006). Thermal, mechanical and electrical properties of copper powder filled low-density and linear low-density polyethylene composites. *Polymer Degradation and stability, 91*(7), 1629-1636.

Ma, X., Yu, J., & Kennedy, J. F. (2005). Studies on the properties of natural fibers-reinforced thermoplastic starch composites. *Carbohydrate polymers, 62*(1), 19-24.

Malkapuram, R., Kumar, V., & Negi, Y. S. (2009). Recent development in natural fiber reinforced polypropylene composites. *Journal of Reinforced Plastics and Composites*, *28*(10).

Mallick, P. K. (2007). *Fiber-reinforced composites: materials, manufacturing, and design*: CRC press.

Manaila, E., Stelescu, M. D., & Doroftei, F. (2015). Polymeric composites based on natural rubber and hemp fibers. *Iranian Polymer Journal, 24*(2), 135-148.

Marques, A., Reis, R., & Hunt, J. (2002). The biocompatibility of novel starch-based polymers and composites: in vitro studies. *Biomaterials, 23*(6), 1471-1478.

Martin, O., & Averous, L. (2001). Poly (lactic acid): plasticization and properties of biodegradable multiphase systems. *Polymer, 42*(14), 6209-6219.

Matthies, P., & Seydl, W. F. (1986). History and development of nylon 6 (pp. 39): Springer.

Medina, L., Schledjewski, R., & Schlarb, A. K. (2009). Process related mechanical properties of press molded natural fiber reinforced polymers. *Composites Science and Technology, 69*(9), 1404-1411.

Methacanon, P., Weerawatsophon, U., Sumransin, N., Prahsarn, C., & Bergado, D. (2010). Properties and potential application of the selected natural fibers as limited life geotextiles. *Carbohydrate polymers, 82*(4), 1090-1096.

Mohanty, A., Khan, M., & Hinrichsen, G. (2000a). Influence of chemical surface modification on the properties of biodegradable jute fabrics—polyester amide composites. *Composites Part A: Applied Science and Manufacturing, 31*(2), 143-150.

Mohanty, A., Misra, M., & Drzal, L. (2002). Sustainable Bio-Composites from Renewable Resources: Opportunities and Challenges in the Green Materials World. *Journal of Polymers and the Environment, 10*(1), 19-26. doi:10.1023/a:1021013921916

Mohanty, A., Misra, M., & Hinrichsen, G. (2000b). Biofibres, biodegradable polymers and biocomposites: an overview. *Macromolecular materials and Engineering, 276*(1), 1-24.

Mohanty, S., Nayak, S., Verma, S., & Tripathy, S. (2004). Effect of MAPP as a coupling agent on the performance of jute–PP composites. *Journal of Reinforced Plastics and Composites, 23*(6), 625-637.

Mohanty, S., & Nayak, S. K. (2006). Interfacial, dynamic mechanical, and thermal fiber reinforced behavior of MAPE treated sisal fiber reinforced HDPE composites. *Journal of Applied Polymer Science, 102*(4), 3306-3315.

Mohanty, S., Verma, S. K., & Nayak, S. K. (2006). Dynamic mechanical and thermal properties of MAPE treated jute/HDPE composites. *Composites Science and Technology, 66*(3), 538-547.

Molitoris, H., Moss, S., De Koning, G., & Jendrossek, D. (1996). Scanning electron microscopy of polyhydroxyalkanoate degradation by bacteria. *Applied microbiology and biotechnology, 46*(5), 570-579.

Mutungi, C., Passauer, L., Onyango, C., Jaros, D., & Rohm, H. (2012). Debranched cassava starch crystallinity determination by Raman spectroscopy: Correlation of features in Raman spectra with X-ray diffraction and 13 C CP/MAS NMR spectroscopy. *Carbohydrate polymers, 87*(1), 598-606.

Nadlene, R., Sapuan, S., Jawaid, M., Ishak, M., & Yusriah, L. (2016). The effects of chemical treatment on the structural and thermal, physical, and mechanical and morphological properties of roselle fiber-reinforced vinyl ester composites. *Polymer composites*.

Nanthaya, K., & Taweechai, A. (2014). A new approach to ‘‘Greening’’ plastic composites using pineapple leaf waste for performance and cost effectiveness. *Materials and Design, 55* 292–299.

Ned J. Chou, S. P. K., Ravi Saraf and Ho-Ming Tong. (2010). *Characterization of Polymers* (C. R. B. a. C. A. E. Jr. Ed. Series Edition ed.). New York, USA.: Momentum Press.

Neto, A. R. S., Araujo, M. A., Barboza, R. M., Fonseca, A. S., Tonoli, G. H., Souza, F. V., . . . Marconcini, J. M. (2015). Comparative study of 12 pineapple leaf fiber varieties for use as mechanical reinforcement in polymer composites. *Industrial Crops and Products, 64*, 68-78.

Neto, A. R. S., Araujo, M. A., Souza, F. V., Mattoso, L. H., & Marconcini, J. M. (2013). Characterization and comparative evaluation of thermal, structural, chemical, mechanical and morphological properties of six pineapple leaf fiber varieties for use in composites. *Industrial Crops and Products, 43*, 529-537.

Nopparut, A., & Amornsakchai, T. (2016). Influence of pineapple leaf fiber and it's surface treatment on molecular orientation in, and mechanical properties of, injection molded nylon composites. *Polymer testing, 52*, 141-149.

Otsuki, H., & Funahashi, H. (1959). Synthesis of Polyamide by Ozonolysis of Oleic Acid: ACS Publications.

Paglicawan, M. A., Kim, B. S., Basilia, B. A., Emolaga, C. S., Marasigan, D. D., & Maglalang, P. E. C. (2014). Plasma-treated abaca fabric/unsaturated polyester composite fabricated by vacuum-assisted resin transfer molding. *International Journal of Precision Engineering and Manufacturing-Green Technology, 1*(3), 241-246.

Palumbo, M., Avellaneda, J., & Lacasta, A. (2015). Availability of crop by-products in Spain: New raw materials for natural thermal insulation. *Resources, Conservation and Recycling, 99*, 1-6.

Panyasart, K., Chaiyut, N., Amornsakchai, T., & Santawitee, O. (2014). Effect of surface treatment on the properties of pineapple leaf fibers reinforced polyamide 6 composites. *Energy Procedia, 56*, 406-413.

Park, J.-M., Quang, S. T., Hwang, B.-S., & DeVries, K. L. (2006). Interfacial evaluation of modified Jute and Hemp fibers/polypropylene (PP)-maleic anhydride polypropylene copolymers (PP-MAPP) composites using micromechanical technique and nondestructive acoustic emission. *Composites Science and Technology, 66*(15), 2686-2699.

Paul, A., Joseph, K., & Thomas, S. (1997). Effect of surface treatments on the electrical properties of low-density polyethylene composites reinforced with short sisal fibers. *Composites Science and Technology, 57*(1), 67-79.

Paul, N. (1980). Some methods for the utilisation of waste from fibre crops and fibre wastes from other crops. *Agricultural Wastes, 2*(4), 313-318.

Peng, P., & She, D. (2014). Isolation, structural characterization, and potential applications of hemicelluloses from bamboo: A review. *Carbohydrate polymers, 112*, 701-720.

Pervaiz, M., & Sain, M. M. (2003). Carbon storage potential in natural fiber composites. *Resources, Conservation and Recycling, 39*(4), 325-340.

Pickering, K. L., Efendy, M. A., & Le, T. M. (2016). A review of recent developments in natural fibre composites and their mechanical performance. *Composites Part A: Applied Science and Manufacturing, 83*, 98-112.

Piggott, M. (2002). *Load bearing fibre composites*: Springer Science & Business Media.

Pötschke, P., & Paul, D. (2003). Formation of co-continuous structures in melt-mixed immiscible polymer blends. *Journal of Macromolecular Science, Part C: Polymer Reviews, 43*(1), 87-141.

Prachayawarakorn, J., Chaiwatyothin, S., Mueangta, S., & Hanchana, A. (2013). Effect of jute and kapok fibers on properties of thermoplastic cassava starch composites. *Materials & Design, 47*, 309-315.

Prasad, N., Agarwal, V. K., & Sinha, S. (2016). Banana fiber reinforced low-density polyethylene composites: effect of chemical treatment and compatibilizer addition. *Iranian Polymer Journal, 25*(3), 229-241.

Rahman, M. R., Islam, M. N., Huque, M. M., Hamdan, S., & Ahmed, A. S. (2010). Effect of chemical treatment on rice husk (RH) reinforced polyethylene (PE) composites. *BioResources, 5*(2), 854-869.

Rajesh, M., & Pitchaimani, J. (2017). Mechanical Properties of Natural Fiber Braided Yarn Woven Composite: Comparison with Conventional Yarn Woven Composite. *Journal of Bionic Engineering, 14*(1), 141-150.

Rana, A., Mandal, A., & Bandyopadhyay, S. (2003). Short jute fiber reinforced polypropylene composites: effect of compatibiliser, impact modifier and fiber loading. *Composites Science and Technology, 63*(6), 801-806.

Rana, A., Mandal, A., Mitra, B., Jacobson, R., Rowell, R., & Banerjee, A. (1998). Short jute fiber-reinforced polypropylene composites: effect of compatibilizer. *Journal of Applied Polymer Science, 69*(2), 329-338.

Ranganathan, N., Oksman, K., Nayak, S. K., & Sain, M. (2016). Structure property relation of hybrid biocomposites based on jute, viscose and polypropylene: The effect of the fibre content and the length on the fracture toughness and the fatigue properties. *Composites Part A: Applied Science and Manufacturing, 83*, 169-175.

Rashid, B., Leman, Z., Jawaid, M., Ghazali, M. J., & Ishak, M. R. (2016). The mechanical performance of sugar palm fibres (ijuk) reinforced phenolic composites. *International Journal of Precision Engineering and Manufacturing, 17*(8), 1001-1008.

Rong, M. Z., Zhang, M. Q., Liu, Y., Yang, G. C., & Zeng, H. M. (2001). The effect of fiber treatment on the mechanical properties of unidirectional sisal-reinforced epoxy composites. *Composites Science and Technology, 61*(10), 1437-1447.

Rout, J., Misra, M., Tripathy, S., Nayak, S., & Mohanty, A. (2001). The influence of fibre treatment on the performance of coir-polyester composites. *Composites Science and Technology, 61*(9), 1303-1310.

Sanyang, M., Sapuan, S., Jawaid, M., Ishak, M., & Sahari, J. (2016). Recent developments in sugar palm (Arenga pinnata) based biocomposites and their potential industrial applications: A review. *Renewable and Sustainable Energy Reviews, 54*, 533-549.

Sapuan, S., & Maleque, M. (2005). Design and fabrication of natural woven fabric reinforced epoxy composite for household telephone stand. *Materials & Design, 26*(1), 65-71.

Sapuan, S., Mohamed, A., Siregar, J. P., & Ishak, M. (2011). Pineapple Leaf Fibers and PALF-Reinforced Polymer Composites *Cellulose Fibers: Bio-and Nano-Polymer Composites* (pp. 325-343): Springer.

Sastra, H., Siregar, J., Sapuan, S., & Hamdan, M. (2006). Tensile properties of Arenga pinnata fiber-reinforced epoxy composites. *Polymer-Plastics Technology and Engineering, 45*(1), 149-155.

Seavey, K. C., Khare, N. P., Liu, Y., Williams, T. N., & Chen, C.-C. (2003). A new phase-equilibrium model for simulating industrial nylon-6 production trains. *Industrial & engineering chemistry research, 42*(17), 3900-3913.

Sena Neto, A. R., Araujo, M. A. M., Souza, F. V. D., Mattoso, L. H. C., & Marconcini, J. M. (2013). Characterization and comparative evaluation of thermal, structural, chemical, mechanical and morphological properties of six pineapple leaf fiber varieties for use in composites. *Industrial Crops and Products, 43*, 529-537. doi:10.1016/j.indcrop.2012.08.001

Shah, A. U. M., Sultan, M. T. H., Cardona, F., Jawaid, M., Talib, A. R. A., & Yidris, N. (2017). Thermal Analysis of Bamboo Fibre and Its Composites. *BioResources, 12*(2), 2394-2406.

Shalwan, A., & Yousif, B. (2013). In State of Art: Mechanical and tribological behaviour of polymeric composites based on natural fibres. *Materials and Design, 48*, 14-24.

Shibata, S., Cao, Y., & Fukumoto, I. (2005). Press forming of short natural fiber-reinforced biodegradable resin: Effects of fiber volume and length on flexural properties. *Polymer testing, 24*(8), 1005-1011.

Shih, Y.-F., Chang, W.-C., Liu, W.-C., Lee, C.-C., Kuan, C.-S., & Yu, Y.-H. (2014). Pineapple leaf/recycled disposable chopstick hybrid fiber-reinforced biodegradable composites. *Journal of the Taiwan Institute of Chemical Engineers*, *45*(4), 2039-2046.

Siracusa, V., Rocculi, P., Romani, S., & Dalla Rosa, M. (2008). Biodegradable polymers for food packaging: a review. *Trends in Food Science & Technology, 19*(12), 634-643.

Siregar, J. P. (2011). Effect of Selected Treatment on Properties of Pineapple Leaf Fibre Reinforced High Impact Polystyrene Composites. *Thesis, Doctor of Philosophy*(Universiti Putra Malaysia).

Siregar, J. P., Sapuan, S., Rahman, M., & Zaman, H. (2010). The effect of alkali treatment on the mechanical properties of short pineapple leaf fibre (PALF) reinforced high impact polystyrene (HIPS) composites. *J. of Food, Agriculture & Environment*, *8*(2), 1103-1108.

Siregar, J. P., Sapuan, S., Rahman, M. Z. A., & Dahlan, K. Z. H. M. (2011). Thermogravimetric Analysis (TGA) and Differential Scanning Calometric (DSC) Analysis of Pineapple Leaf Fibre (PALF) Reinforced High Impact Polystyrene (HIPS) Composites. *Pertanika Jour-nal of Science and Technology, 19*(1), 161-170.

Siti Zanariah Satari, C. Z. L., Farahanim Misni, Norhafizah Moslim, Noryanti Muhammad, Roslinazairimah Zakaria and Siti Roslindar Yaziz. (2015). *Applied Statistic Module*. Malaysia: Universiti Malaysia Pahang.

Smith, W. F., & Hashemi, J. (2011). *Foundations of materials science and engineering*: McGraw-Hill.

Steller, R., & Meissner, W. (1998). Structure and properties of degradable polyolefin-starch blends. *Polymer Degradation and stability, 60*(2-3), 471-480.

Stocchi, A., Lauke, B., Vázquez, A., & Bernal, C. (2007). A novel fiber treatment applied to woven jute fabric/vinylester laminates. *Composites Part A: Applied Science and Manufacturing, 38*(5), 1337-1343.

Štrumberger, N., Gospočić, A., & Bartulić, Č. (2005). Polymeric materials in automobiles. *PROMET-Traffic & Transportation, 17*(3), 149-160.

Su, R., Wang, K., Zhang, Q., Chen, F., & Fu, Q. (2010). Effect of melt temperature on the phase morphology, thermal behavior and mechanical properties of injection-molded PP/LLDPE blends. *Chinese Journal of Polymer Science, 28*(2), 249-255.

Sun, Q., Zhao, X., Wang, D., Dong, J., She, D., & Peng, P. (2018). Preparation and characterization of nanocrystalline cellulose/Eucommia ulmoides gum nanocomposite film. *Carbohydrate polymers, 181*, 825-832.

Szeteiová, K. (2010). Automotive materials plastics in automotive markets today. *Institute of Production Technologies, Machine Technologies and Materials, Faculty of Material Science and Technology in Trnava, Slovak University of Technology Bratislava*.

Takagi, H., & Ichihara, Y. (2004). Effect of fiber length on mechanical properties of" green" composites using a starch-based resin and short bamboo fibers. *JSME International Journal Series A, 47*(4), 551-555.

Tao, Y., Yan, L., & Jie, R. (2009). Preparation and properties of short natural fiber reinforced poly (lactic acid) composites. *Transactions of Nonferrous Metals Society of China, 19*, s651-s655.

TAPPI. (1997). TAPPI T264 cm-97. Preparation of Wood for Chemical Analysis. Atlanta, GA: TAPPI Press.

TAPPI. (1999). TAPPI T203 cm-99, Alpha-, Beta-, and Gamma-Cellulose in Pulp. Atlanta, GA: TAPPI Press.

TAPPI. (2002). TAPPI T222 om-02, Acid-Insoluble Lignin in Wood and Pulp. Atlanta, GA: TAPPI Press.

Threepopnatkul, P., Kaerkitcha, N., & Athipongarporn, N. (2009). Effect of surface treatment on performance of pineapple leaf fiber–polycarbonate composites. *Composites Part B: Engineering, 40*(7), 628-632.

Tian, X., Wang, B., Wang, B., Li, J., & Chen, K. (2017). Structural Characterization of Lignin Isolated from Wheat-Straw during the Alkali Cooking Process. *BioResources, 12*(2), 2407-2420.

Tong, J. Y., Royan, N. R. R., Ng, Y. C., Ab Ghani, M. H., & Ahmad, S. (2014). Study of the mechanical and morphology properties of recycled HDPE composite using rice husk filler. *Advances in Materials Science and Engineering, 2014*.

Tungjitpornkull, S., & Sombatsompop, N. (2009). Processing technique and fiber orientation angle affecting the mechanical properties of E-glass fiber reinforced wood/PVC composites. *journal of materials processing technology, 209*(6), 3079-3088.

Väisänen, T., Das, O., & Tomppo, L. (2017). A review on new bio-based constituents for natural fiber-polymer composites. *Journal of Cleaner Production, 149*, 582-596.

Valadez-Gonzalez, A., Cervantes-Uc, J., Olayo, R., & Herrera-Franco, P. (1999). Effect of fiber surface treatment on the fiber–matrix bond strength of natural fiber reinforced composites. *Composites Part B: Engineering, 30*(3), 309-320.

Valášek, P., D'Amato, R., Müller, M., & Ruggiero, A. (2018). Musa textilis Cellulose Fibres in Biocomposites–An Investigation of Mechanical Properties and Microstructure. *BioResources, 13*(2), 3177-3194.

Valášek, P., Ruggiero, A., & Müller, M. (2017). Experimental description of strength and tribological characteristic of EFB oil palm fibres/epoxy composites with technologically undemanding preparation. *Composites Part B: Engineering, 122*, 79-88.

Vink, E. T., Rabago, K. R., Glassner, D. A., & Gruber, P. R. (2003). Applications of life cycle assessment to NatureWorks™ polylactide (PLA) production. *Polymer Degradation and stability, 80*(3), 403-419.

Wahrmund, D., Paul, D., & Barlow, J. (1978). Polyester–polycarbonate blends. I. Poly (butylene terephthalate). *Journal of Applied Polymer Science, 22*(8), 2155-2164.

Westman, M., Laddha, S., Fifield, L., Kalentzis, T., & Simmons, K. (2010). Natural Fiber Composites: A Review. *U.S. Department of Energy under Contract DE-AC05-76LD01830, PNNL-19220*.

Wise, L. E., Murphy, M., & D'Addieco, A. A. (1946). Paper Trade J., 122, No. 2, 35 (1946). *Tech. Assoc. Papers, 29*, 210.

Xia, X., Shi, X., Liu, W., Zhao, H., Li, H., & Zhang, Y. (2017). Effect of flax fiber content on polylactic acid (PLA) crystallization in PLA/flax fiber composites. *Iranian Polymer Journal, 26*(9), 693-702.

Xu, Y., & Wu, P. (2007). A study of water dehydration in nylon 6 as a function of temperature using two-dimensional (2D) correlation near-infrared (NIR) analysis. *Journal of molecular structure, 833*(1), 145-149.

Yang, H.-S., Wolcott, M. P., Kim, H.-S., Kim, S., & Kim, H.-J. (2007). Effect of different compatibilizing agents on the mechanical properties of lignocellulosic material filled polyethylene bio-composites. *Composite Structures, 79*(3), 369-375.

Yang, K., & El-Haik, B. S. (2003). *Design for six sigma*: McGraw-Hill New York.

Yousif, B., Shalwan, A., Chin, C., & Ming, K. (2012). Flexural properties of treated and untreated kenaf/epoxy composites. *Materials & Design, 40*, 378-385.

Yu, T., Ren, J., Li, S., Yuan, H., & Li, Y. (2010). Effect of fiber surface-treatments on the properties of poly (lactic acid)/ramie composites. *Composites Part A: Applied Science and Manufacturing, 41*(4), 499-505.

Yun, I. S., Hwang, S. W., Shim, J. K., & Seo, K. H. (2016). A study on the thermal and mechanical properties of poly (butylene succinate)/thermoplastic starch binary blends. *International Journal of Precision Engineering and Manufacturing-Green Technology, 3*(3), 289-296.

Zampaloni, M., Pourboghrat, F., Yankovich, S., Rodgers, B., Moore, J., Drzal, L., . . . Misra, M. (2007). Kenaf natural fiber reinforced polypropylene composites: a discussion on manufacturing problems and solutions. *Composites Part A: Applied Science and Manufacturing, 38*(6), 1569-1580.

Zhong, J., Li, H., Yu, J., & Tan, T. (2011). Effects of natural fiber surface modification on mechanical properties of poly (lactic acid)(PLA)/sweet sorghum fiber composites. *Polymer-Plastics Technology and Engineering, 50*(15), 1583-1589.